Default Values:

Drop Placement, Aerial & Buried		
Density Zone	**Aerial, total**	**Buried, per foot**
0-5	$23.33	$0.60
5-100	$23.33	$0.60
100-200	$17.50	$0.60
200-650	$17.50	$0.60
650-850	$11.67	$0.60
850-2,550	$11.67	$0.60
2,550-5,000	$11.67	$0.75
5,000-10,000	$11.67	$1.50
10,000+	$11.67	$5.00

Support:

Aerial Drop Placement:

The opinions of expert outside plant engineers and estimators were used to project the amount of time necessary to attach a drop wire clamp at a utility pole, string the drop, and attach a drop wire clamp at the house or building. Labor to terminate the drop at the NID and the Block Terminal is included in the NID and Block Terminal investments respectively.

The labor estimate assumes a crew installing aerial drop wires throughout a neighborhood (in coordination with the installation of NIDs, terminals, and distribution cables), and consists of 10 minutes per drop plus 10 minutes for each 50 ft. of drop strung. The loaded labor rate excludes exempt material loadings which normally include the material cost of the Aerial Drop Wire.

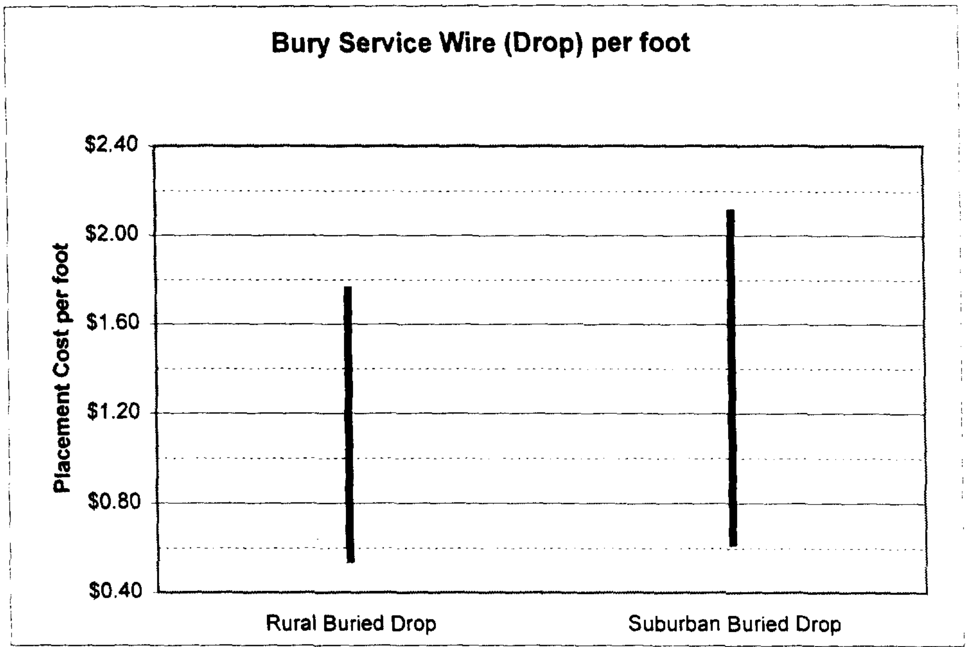
Aerial Drop Placement				
Density Zone	**Aerial Drop Length (ft.)**	**Installation Time (min.)**	**Direct Loaded Labor Rate $/hr.**	**Aerial Total**
0-5	150	40	$35	$23.33
5-100	150	40	$35	$23.33
100-200	100	30	$35	$17.50
200-650	100	30	$35	$17.50
650-850	50	20	$35	$11.67
850-2,550	50	20	$35	$11.67
2,550-5,000	50	20	$35	$11.67
5,000-10,000	50	20	$35	$11.67
10,000+	50	20	$35	$11.67

Buried Drop Placement

The labor estimate is based on a crew installing buried drop wires throughout a neighborhood (in coordination with the installation of NIDs, terminals, and distribution cables).

Of the quotes that were received for suburban and rural buried drop placement, several of them price buried drop placement at the HM 5.0a default values. Because buried drops are rare in urban areas, the expert opinion of outside plant experts was used in lieu of verifiable forward looking alternatives from public sources or ILECs.

Price quotes for contractor placement of buried drop wire were as follows:



2.2.3. Buried Drop Sharing Fraction

Definition: The fraction of buried drop cost that is assigned to the telephone company. The other portion of the cost is borne by other utilities.

Default Values:

Buried Drop Sharing Fraction	
Density Zone	**Fraction**
0-5	.50
5-100	.50
100-200	.50
200-650	.50
650-850	.50
850-2,550	.50
2,550-5,000	.50
5,000-10,000	.50
10,000+	.50

Support: Drop wires in new developments are most often placed in conjunction with other utilities to achieve cost sharing advantages, and to ensure that one service provider does not cut another's facilities during the trenching or plowing operation.

Conversations with architects and builders indicate that the builder will most often provide the trench at no cost, and frequently places electric, telephone, and cable television facilities into the trench if material is delivered on site. Research done in Arizona has indicated that developers not only provide trenches, but also provide small diameter PVC conduits across front property lines to facilitate placement of wires.

The HAI Model version 5.0a determines the sharing of buried drop structures based on density zones. It is the judgment of outside plant experts that buried drops will normally be used with buried distribution cable. Although many cases would result in three-way sharing of such structure, a conservative approach was to use 50% sharing.

2.2.4. Aerial and Buried Drop Structure Fractions

Definition: The percentage of drops that are aerial and buried, respectively, as a function of density zone.

Default Values:

Drop Structure Fractions		
Density Zone	**Aerial**	**Buried**
0-5	.25	.75
5-100	.25	.75
100-200	.25	.75
200-650	.30	.70
650-850	.30	.70
850-2,550	.30	.70
2,550-5,000	.30	.70
5,000-10,000	.60	.40
10,000+	.85	.15

Support: The HAI Model version 5.0a determines the use of distribution structures based on density zones. It is the judgment of outside plant experts that aerial drops will normally be used with aerial distribution cable and buried drops with buried and underground distribution cable. Therefore, the percentage of aerial drops equals the percentage of aerial distribution cable (see Section 2.5). The high percentage of aerial drops in the two most dense zones reflects the fact that such drops, if present at all, are extensions of riser cable, which is treated as aerial.

2.2.5. Average Lines per Business Location

Definition: The average number of business lines per business location, used to calculate NID and drop cost. This parameter should be set the same as 5.4.15.

Default Value:

Number of Lines per Business Location
4

Support: The number of lines per business location estimated by HAI is based on data in the *1995 Common Carrier Statistics* and the *1995 Statistical Abstract of the United States.*

2.2.6. Aerial and Buried Terminal and Splice per Line

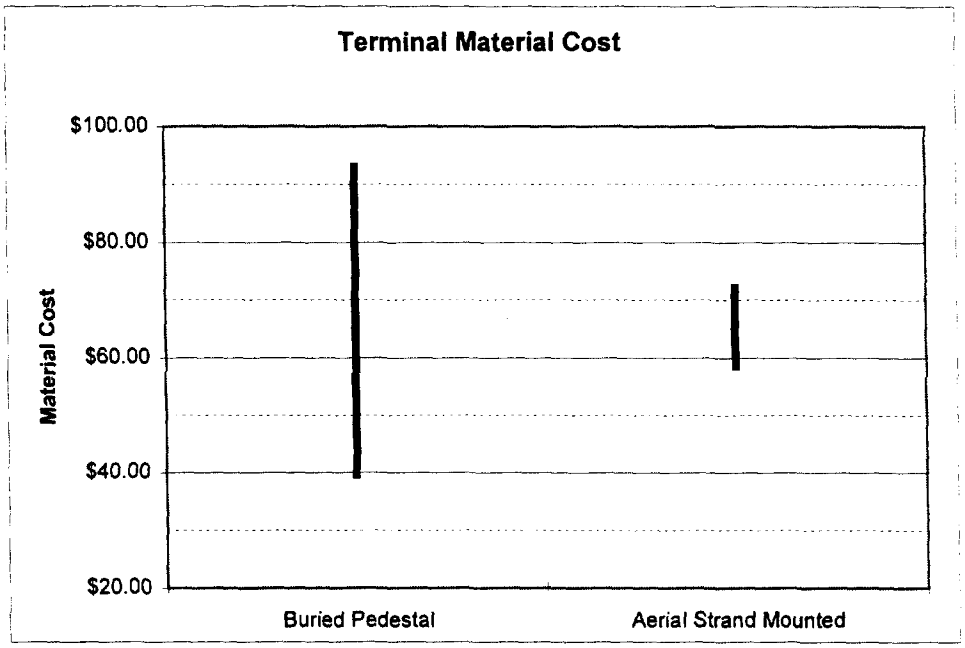
Definition: The installed cost per line for the terminal and splice that connect the drop to the distribution cable.

Default Values:

Terminal and Splice Investment per Line	
Buried	**Aerial**
$42.50	$32.00

Support: The figures above represent 25% of the cost of a terminal assuming a terminal is shared between four premises. The full cost is $128 Aerial and $170 Buried for both material and labor for 25 pair terminals. HM 5.0a assigns this investment per line in all but the two lowest density zones, where the cost is doubled to represent two premises served per terminal.

Price quotes for just the material portion were received from several sources. Results were as follows:



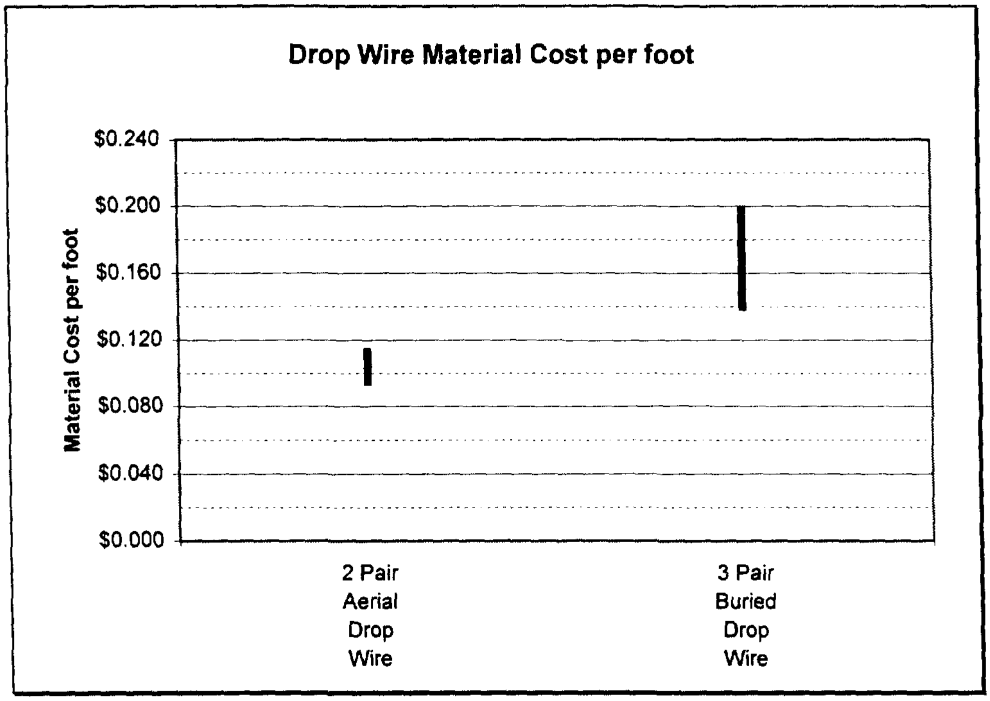
2.2.7. Drop Cable Investment, per Foot and Pairs per Drop

Definition: The investment per foot required for aerial and buried drop wire, and the number of pairs in each type of drop wire.

Default Values:

Drop Cable Investment, per foot		
	Material Cost Per foot	Pairs
Aerial	$0.095	2
Buried	$0.140	3

Support: Price quotes for material were received from several sources. Results were as follows:



2.3 CABLE AND RISER INVESTMENT

2.3.1. Distribution Cable Sizes

Definition: Cable sizes used for distribution cable variables (in pairs).

Default Values:

Cable Sizes
2400
1800
1200
900
600
400
200
100
50
25
12
6

Support: Distribution plant connects feeder plant, normally terminated at a Serving Area Interface (SAI), to the customer's block terminal. "Distribution network design requires more distribution pairs than feeder pairs, so distribution cables are more numerous, but smaller in cross section, than feeder cables."[3] The HAI Model default values represent the array of distribution cable sizes assumed to be available for placement in the network. Although three additional sizes of distribution cable (2100 pair, 1500 pair, and 300 pair cable) can be used, the industry has largely abandoned use of those sizes in favor of reduced, simplified inventory.

2.3.2. Distribution Cable, Cost per Foot

Definition: The cost per foot of copper distribution cable, as a function of cable size, including the costs of engineering, installation, and delivery, as well as the cable material itself.

[3] Bellcore, *Telecommunications Transmission Engineering*, 1990, p. 91.

Default Values:

Copper Distribution Cable, $/foot	
Cable Size	**Cost/foot (including engineering, installation, delivery and material)**
2400	$20.00
1800	$16.00
1200	$12.00
900	$10.00
600	$7.75
400	$6.00
200	$4.25
100	$2.50
50	$1.63
25	$1.19
12	$0.76
6	$0.63

Support: These costs reflect the use of 24-gauge copper distribution cable for cable sizes below 400 pairs, and 26-gauge copper distribution cable for cable sizes of 400 pairs and larger. Although 24-gauge copper is not required for transmission requirements within 18,000 feet of a digital central office with a 1,500 ohm limit, or a GR-303 integrated digital loop carrier system with a 1,500 ohm limit, a heavier gauge of copper is used in smaller cable sizes to prevent damage from craft handling wires in distribution terminals and pedestals. For cables of 400 pairs and larger, splices are normally enclosed in splice cases, and are not subject to wire handling problems.

Cable below 400 Pairs: Outside plant planning engineers commonly assume that the cost of cable material can be represented as an a + bx straight line graph. In fact, Bellcore Planning tools, EFRAP I, EFRAP II, and LEIS:PLAN have the engineer develop such an a + bx equation to represent the cost of cable. As technology, manufacturing methods, and competition have advanced, the price of cable has been reduced. While in the past, the cost of copper cable was typically ($0.50 + $0.01 per pair) per foot, current costs are typically ($0.30 + $0.007 per pair) per foot.

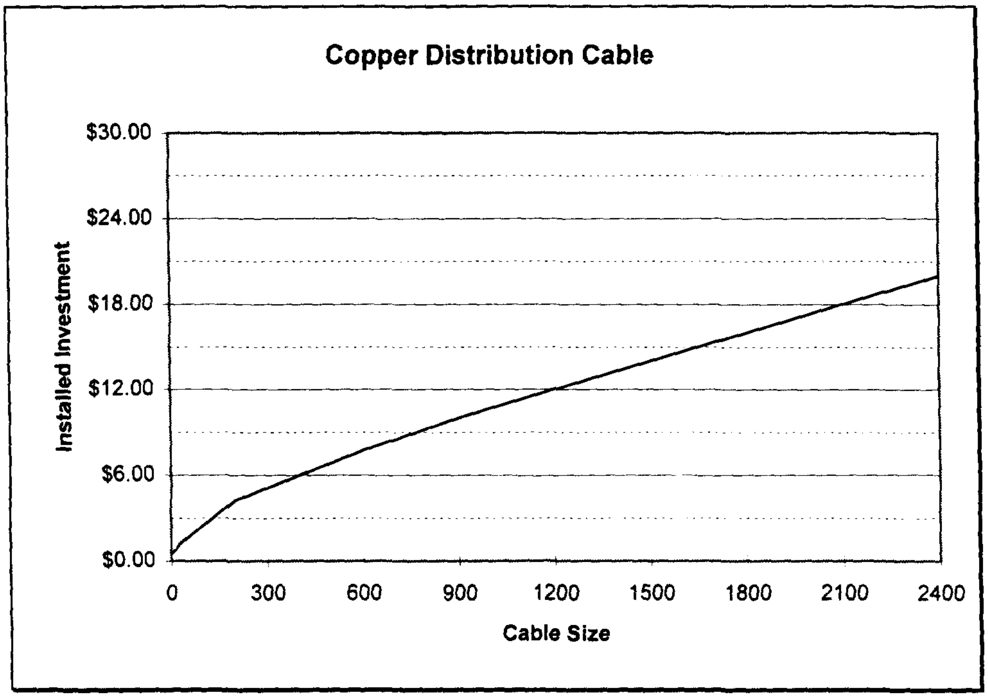
In the opinion of expert outside plant engineers whose experience includes writing and administering hundreds of outside plant "estimate cases" (large undertakings), material represents approximately 40% of the total installed cost. This is a widely used rule of thumb among outside plant engineers. Such expert opinions were also used to determine that the average engineering content for installed copper cable is 15% of the installed cost. The remaining 45% represents direct labor for placing and splicing cable, exclusive of the cost of splicing block terminals into the cable.[4]

Cable of 400 Pairs and Larger: As copper cable sizes become larger, engineering cost is based more and more on sheath feet, rather than cable size. The same is true for cable placing and splice set-up. Therefore the linear relationship between the number of copper pairs and installed cost is somewhat reduced. A

[4] The formula would produce a material price of $0.38/ft. for 12 pair 24 gauge cable, and $0.34/ft. for 6 pair 24 gauge cable. An actual quote for materials was obtained at $0.18/ft. for 12 pair 24 gauge cable, and $0.12/ft. for 6 pair 24 gauge cable. The significant difference in material cost is perceived to be the result of the very small quantity of sheath required for 12 and 6 pair cables. Therefore, the formula generated material price was reduced by $0.20 and $0.22 for 12 and 6 pair cables respectively, but the engineering and labor components were retained at original formula levels, since neither would be affected by the reduction in material price.

review of many installed cable costs around the country were used by the engineering team to estimate the installed cost of copper cable for sizes of 400 pairs and larger.

The following chart represents the values used in the model.



2.3.3. Riser Cable Size and Cost per Foot

Definition: The cost per foot of copper riser cable (cable inside high-rise buildings), as a function of cable size, including the costs of engineering, installation, and delivery, as well as the cable material itself.

Default Values:

Riser Cable, $/foot	
Cable Size	Cost/foot (including engineering, installation, delivery and material)
2400	$25.00
1800	$20.00
1200	$15.00
900	$12.50
600	$10.00
400	$7.50
200	$5.30
100	$3.15
50	$2.05
25	$1.50
12	$0.95
6	$0.80

Support: Riser cable is assumed to cost approximately 25% more than aerial copper distribution cable. Material cost is slightly higher, and the amount of engineering and direct labor per foot is higher than aerial cable.

2.4. POLES AND CONDUIT

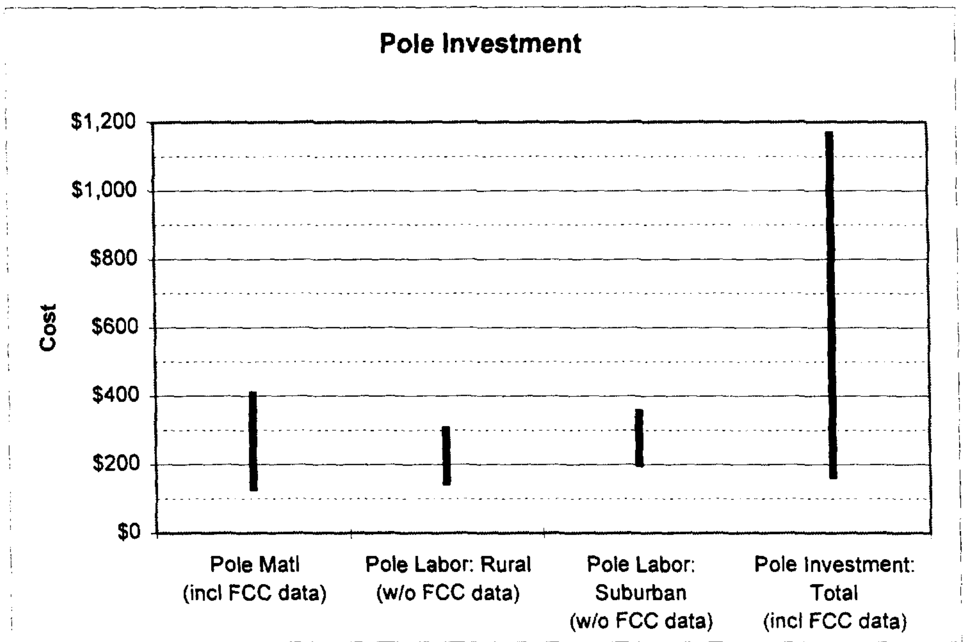
2.4.1. Pole Investment

Definition: The installed cost of a 40-foot Class 4 treated southern pine utility pole.

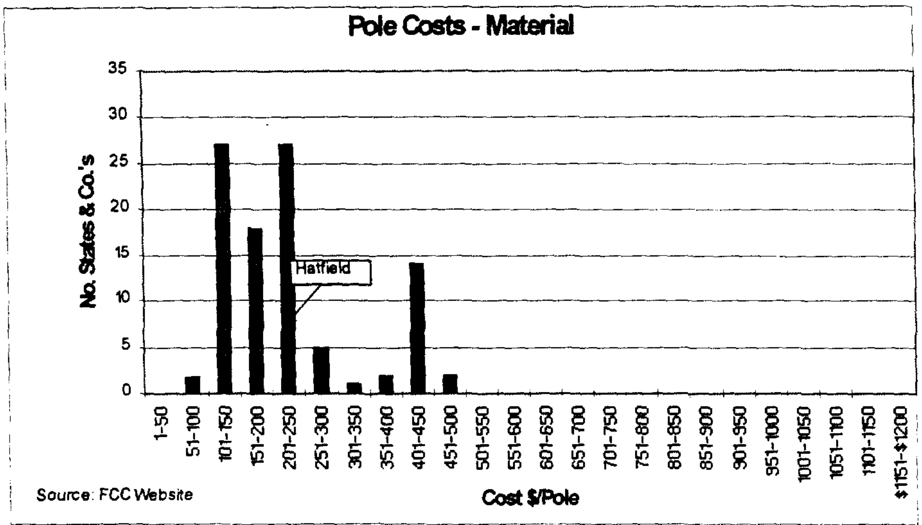
Default Values:

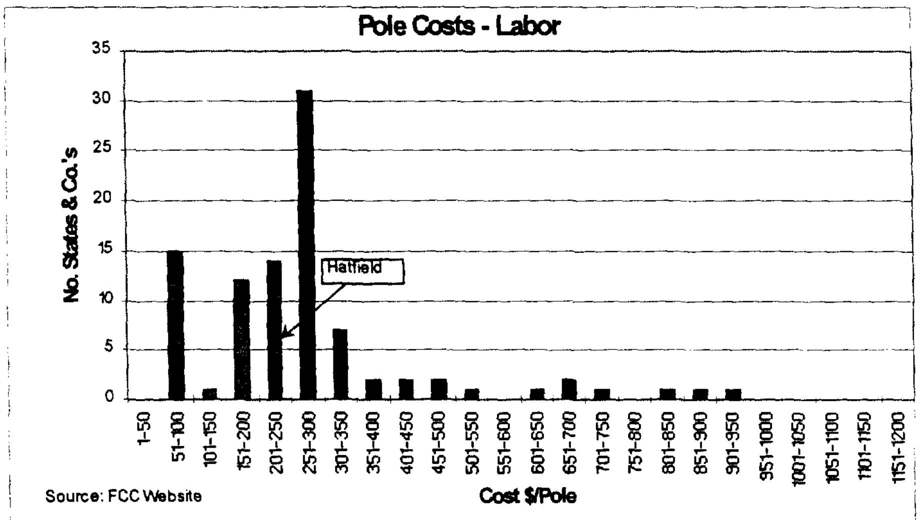
Pole Investment	
Materials	$201
Labor	$216
Total	*$417*

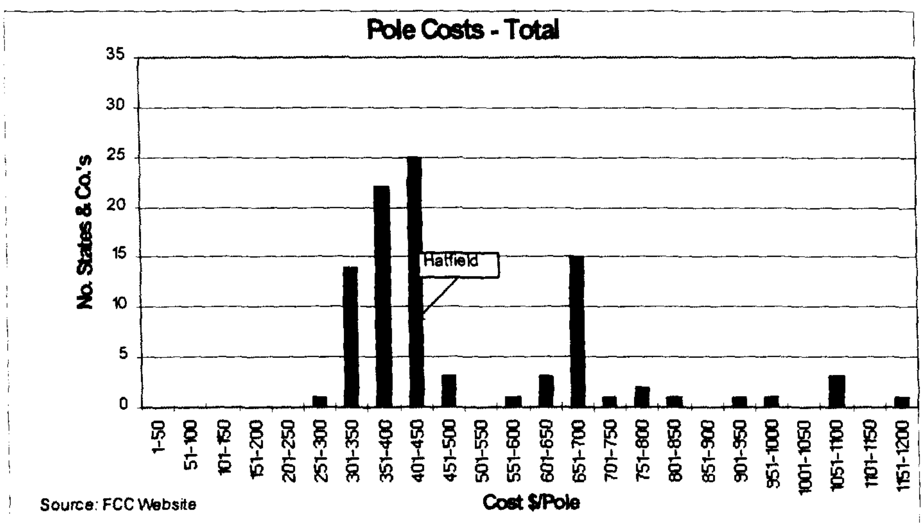
Support: Pole investment is a function of the material and labor costs of placing a pole. Costs include periodic down-guys and anchors. Utility poles can be purchased and installed by employees of ILECs, but are frequently placed by contractors. Several sources revealed the following information on prices.



Pole data has also been recently filed by large telephone companies with the FCC. A compilation of that information is shown below:


Pole Costs - Material
No. States & Co.'s
Hatfield
Cost $/Pole
Source: FCC Website


Pole Costs - Labor
No. States & Co.'s
Hatfield
Cost $/Pole
Source: FCC Website


Pole Costs - Total
No. States & Co.'s
Hatfield
Cost $/Pole
Source: FCC Website

The exempt material load on direct labor includes ancillary material not considered by FCC Part 32 as a unit of plant. That includes items such as downguys and anchors that are already included in the pole placement labor cost. Outside plant engineering experts have concluded that a typical anchor plus anchor rod material investment is $45, and the typical guy material investment is $10. Also, one anchor and downguy per 1,000 feet would be typical. Therefore the embedded anchor and guy exempt material loading included in the default value of $216 is approximately $8.25 - $13.75 per pole.

The steel strand run between poles is likewise an exempt material item, charged to the aerial cable account. The cost of steel strand is not included in the cost of poles; it is included in the installed cost of aerial cable.

2.4.2. Buried Copper Cable Sheath Multiplier (feeder and distribution)

Definition: The additional cost of the filling compound used in buried cable to protect the cable from moisture, expressed as a multiplier of the cost of non-filled cable.

Default Value:

Buried Copper Cable Sheath Multiplier	
Multiplier	1.04

Support: Filled cable is designed to minimize moisture penetration in buried plant. This factor accounts for the extra investment incurred by using more expensive cable and splicing procedures, designed specifically for buried application.

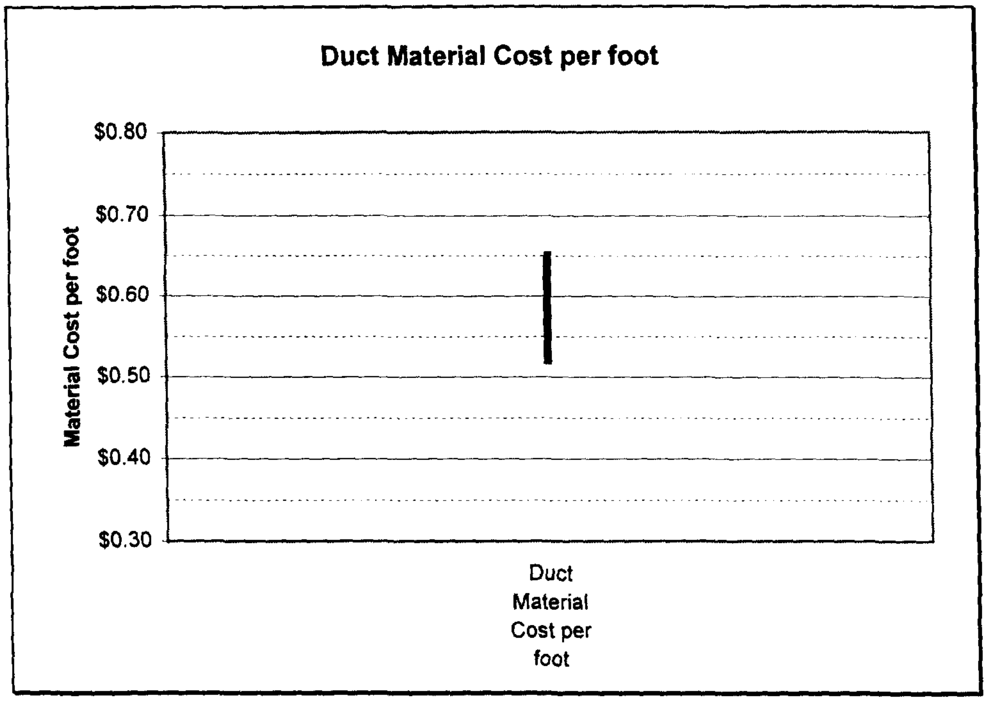
2.4.3. Conduit Material Investment per Foot

Definition: Material cost per foot of 4" PVC pipe.

Default Values:

Material cost per foot of duct for 4" PVC	
4" PVC	$0.60

Support: Several suppliers were contacted for material prices. Results are shown below.



The labor to place conduit in trenches is included in the cost of the trench, not in the conduit cost.

Under the Model's assumptions, a relatively few copper cables serving short distances (e.g., less than 9,000 ft. feeder cable length), and one or more fiber cables to serve longer distances, will be needed. Since the number of cables in each of the four feeder routes is relatively small, the predominant cost is that of the trench, plus the material cost of a few additional 4" PVC conduit pipes.

2.4.4. Spare Tubes per Route

Definition: The number of spare tubes (i.e., conduit) placed per route.

Default Value:

Spare Tubes per Route	
# Spare Tubes	1

Support: "A major advantage of using conduits is the ability to reuse cable spaces without costly excavation by removing smaller, older cables and replacing them with larger cables or fiber facilities. Some companies reserve vacant ducts for maintenance purposes."[5] Version 5.0a of the HAI Model provides one spare maintenance duct (as a default) in each conduit run. In addition, if there is also a fiber feeder cable along with a copper feeder cable in the run, an additional maintenance duct (as a default) is provided in each conduit run to facilitate a fiber cable replacement at the same time a copper cable replacement may be required.

[5] Bellcore, *BOC Notes on the LEC Networks - 1994*, p. 12-42.

2.5. BURIED, AERIAL, AND UNDERGROUND PLACEMENT FRACTION

General:

Outside plant structure refers to the set of facilities that support, house, guide, or otherwise protect distribution and feeder cable. There are three types of structure: aerial, buried, and underground.

a) Aerial Structure

Aerial structure includes poles and associated hardware.[6] Pole investment is a function of the material and labor costs of placing a pole. A user-adjustable input adjusts the labor component of poles investment to local conditions. The HAI Model computes the total investment in aerial distribution and feeder structure within a study area by evaluating relevant parameters, including the distance between poles, the investment in the pole itself, the total cable sheath mileage, and the fraction of aerial structure along the route.

Poles are assumed to be 40 foot Class 4 poles. The spacing between poles for aerial cable is fixed within a given density range, but may vary between density ranges.

b) Buried Structure

Buried structure consists of trenches. The additional cost for protective sheathing and waterproof filling of buried cable is a fixed amount per foot in the case of fiber cable, and is a multiplier of cable cost in the case of copper cable.[7] The total investment in buried structure is a function of total route mileage, the fraction of buried structure, investment in protective sheathing and filling and the density-range-specific cost of trenching.

c) Underground Structure

Underground structure consists of conduit and, for feeder plant, manholes and pullboxes. Manholes are used in conjunction with copper cable routes; pullboxes are used with fiber cable. The total investment in a manhole varies by density zone, and is a function of the following investments: materials, frame and cover, excavation, backfill, and site delivery. Investment in fiber pullboxes is a function of materials and labor. Underground cables are housed in conduit facilities that extend between manholes or pullboxes. The total investment in underground structure is a function of total route mileage, the fraction of underground structure, investment in conduit, manholes and pullboxes for copper and fiber feeder or plant, and the cost of trenching needed to hold the conduit.

In each line density range, there may be a mixture of aerial, buried, and underground structure. For example, in downtown urban areas it is frequently necessary to install cable in underground conduit systems, while rural areas may consist almost exclusively of aerial or direct-buried plant. Users can adjust the mix of aerial, underground and buried cable assumed within the HAI model. These settings may be made separately by density zone for fiber feeder, copper feeder, and copper distribution cables.

d) Buried Fraction Available for Shift

[6] In the two highest density zones, aerial structure is also assumed to consist of intrabuilding riser cable and "block cable" attached to buildings. In HM 5.0a this "aerial" structure does not include poles.

[7] The default values for sheathing are an additive $0.20 per foot for fiber and a multiplier of 1.04 for copper. The different treatment reflects the fact that the outside dimension of fiber cable is essentially constant for different strand numbers, while the dimension of copper cable increases with the number of pairs it contains.

This input addresses the ability of the model to perform a dynamic calculation to determine the most efficient life-cycle costs of buried vs. aerial structure. The calculation considers the different values involved in buried vs. aerial structure in terms of initial investment, sub-surface conditions, soil texture, percent structure sharing, depreciation rates, and maintenance costs.

Underground conduit is not considered as a candidate for structure shifting, since the motivation for placing underground conduit and cable is usually a function of high pavement costs and the need to allow for future replacement and addition of cables without disturbing the above ground pavement conditions.

2.5.1 Distribution Structure Fractions

Definition: The relative amounts of different structure types supporting distribution cable in each density zone. In the highest two density zones, aerial structure includes riser and block cable.

Default Values: See under 2.5.2, below.

Support: It is the opinion of outside plant engineering experts that density, measured in Access Lines per Square Mile, is a good determinant of structure type. That judgment is based on the fact that increasing density drives more placement in developed areas, and that as developed areas become more dense, placements will more likely occur under pavement conditions.

Aerial/Block Cable:

"The most common cable structure is still the pole line. Buried cable is now used wherever feasible, but pole lines remain an important structure in today's environment."[8]

Where an existing pole line is available, cable is normally placed on the existing poles. Abandoning an existing pole line in favor of buried plant is not usually done unless such buried plant provides a much less costly alternative.

HM 5.0a accounts for drop wire separately; drop wire is not considered part of aerial cable in HM 5.0a. However, cable attached to the [out]sides of buildings, normally found in higher density areas, is appropriately classified to the aerial cable account. To facilitate modeling, HM 5.0a also reasonably includes Intrabuilding Network Cable under its treatment of aerial cable.

Therefore, the default percentages above 2,550 lines per square mile indicate a growing amount of block and intrabuilding cable, rather than cable placed on pole lines (although existing joint use pole lines are also more prevalent in older, more dense neighborhoods built prior to 1980).

Buried Cable:

Default values in HM 5.0a reflect an increasing trend toward use of buried cable in new subdivisions. Since 1980, new subdivisions have usually been served with buried cable for several reasons. First, before 1980, cables filled with water blocking compounds had not been perfected. Thus, prior to that time, buried cable was relatively expensive and unreliable. Second, reliable splice closures of the type required for buried facilities were not the norm. And third, the public now clearly desires more out-of-sight plant for both aesthetic and safety-related reasons. Contacts with telephone outside plant engineers, architects and property developers in several states confirm that in new subdivisions, builders typically not only prefer buried plant that is capable of accommodating multiple uses, but they usually dig the trenches at their own expense and place power, telephone, and CATV cables in the trenches, if the utilities are willing to supply the materials. Thus, many buried structures are available to the LEC at no charge, although the Model does not reflect such savings.

[8] Bellcore, *BOC Notes on the LEC Networks - 1994*, p. 12-41.

Underground Cable:

Underground cable, conduit, and manholes are primarily used for feeder and interoffice transport cables, not for distribution cable. Distribution plant in congested, extensively paved, high density areas usually runs only a short distance underground from the SAI to the block terminal, thus it requires no intermediate splicing chambers. In high density residential areas, distribution cables are frequently run from pole lines, under a street, and back up onto a pole line, or from buried plant, under a street, and back to a buried cable run. Such conduit runs are short enough to not require a splicing chamber or manhole and are therefore classified to the aerial or buried cable account, respectively.

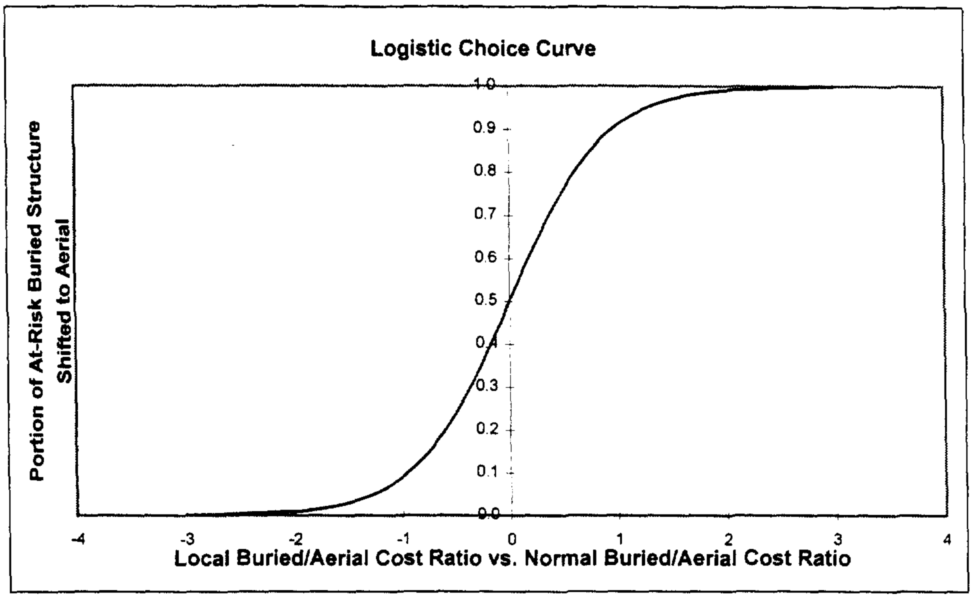
There may be rare exceptions where distribution cable from a SAI is so long that it requires an underground splicing chamber (manhole). Sometimes feeder cable will be extended, via a lateral, into a SAI, and distribution pairs in the same feeder stub will run back into the same manhole for further routing to aerial or buried structures down a street. In those cases, manholes and conduit were placed for feeder cable and have already been accounted for in the cost of feeder plant structure. To account for such manholes and conduit in distribution plant as well would result in double counting the cost.

In a "campus environment," where underground structure is used, it is owned and operated by the owner of the campus and not the ILEC. The cable is treated as Intrabuilding Network Cable between buildings on one customer's premises, and the cost of such cable is not included in the model.

2.5.2 Buried Fraction Available for Shift

Fraction of buried cable structure input value available to be shifted from buried to aerial or aerial to buried (if the model finds abnormal local terrain conditions making such a shift advantageous, a check in the model preventing percent aerial from going below zero). If the user has entered, for example, an initial value of 0.40 for the buried cable fraction in a given density zone and then enters 0.75 as the buried fraction available for shift, the model can allow the computed buried fraction (according to changes in the relative costs of buried versus aerial structure occasioned by local surface and bedrock conditions) to vary between 0.10 (= 0.40 - 75% of 0.40) and 0.70 (= 0.40 + 75% of 0.40) – subject to the implied aerial fraction remaining non-negative.

HM 5.0a uses a "Logistic Choice Curve" to control the sensitivity of the shift in structure to changes in the local relative cost of buried versus aerial plant. In the chart below, the horizontal axis represents the ratio of the local buried to aerial cost ratio to the national norm buried to aerial cost ratio. Its scale is logarithmic, thus the value of zero indicates that the local cost ratio equals the national cost ratio. Increasing positive values indicate the local buried to aerial cost ratio rising relative to the national ratio – as would occur if local soil conditions were rockier than normal. Negative values indicate a local buried to aerial cost ratio that is less than the national ratio. The vertical axis represents the portion of "swing" buried plant that is shifted to aerial. At a value of 0.5, there is no net movement of "swing" buried structure away from the national default percentage.



Default Values:

Distribution Cable Structure Fractions				
Density Zone	Aerial/Block Cable	Buried Cable	Underground Cable (calculated)	Buried Fraction Available for Shift
0-5	.25	.75	0	.75
5-100	.25	.75	0	.75
100-200	.25	.75	0	.75
200-650	.30	.70	0	.75
650-850	.30	.70	0	.75
850-2,550	.30	.70	0	.75
2,550-5,000	.30	.65	.05	.75
5,000-10,000	.60	.35	.05	-
10,000+	.85	.05	.10	-

Support: Since shifting of structure type from buried to aerial, or vice versa is permitted, the HAI Model allows the user to affect such shifting by the application of engineering judgment. There may be local ordinances or regulatory rules, that encourage utilities to place out-of-sight facilities under certain conditions. Therefore, should aerial structure be the most economic solution in a particular cable section, the model could shift all buried structure to aerial. However, in the event such shifting is not practical, the HAI Model allows the user to reserve a percentage of buried cable structure, regardless of the opportunity for a shift to less expensive aerial cable. A team of outside plant engineering experts recommend that only 75% of the buried percentage be allowed to shift to aerial.

The user should note that this default value can be adjusted to 100% to allow the model to optimize the cable structure choice between aerial and buried structure without constraint.

2.6. CABLE SIZING FACTORS AND POLE SPACING

2.6.1. Distribution Cable Sizing Factors

Definition: The factor by which distribution cable is increased above the size needed to serve a given quantity of demand in order to provide spare pairs for breakage, line administration, and some amount of growth. HM 5.0a divides the number of pairs needed in a distribution cable to meet existing demand by this factor to determine the minimum number of pairs required, then uses the next larger available size cable.

Default Values:

Distribution Cable Sizing Factors	
Density Zone	**Factors**
0-5	.50
5-100	.55
100-200	.55
200-650	.60
650-850	.65
850-2,550	.70
2,550-5,000	.75
5,000-10,000	.75
10,000+	.75

Support: In determining appropriate cable size, an outside plant engineer is more interested in a sufficient number of administrative spares than in the percent-sizing ratio. The appropriate distribution cable sizing factor, therefore, will vary depending upon the size of cable. For example, 75% utilization in a 2400 pair cable provides 600 spares. However, 50% utilization in a 6 pair cable provides only 3 spares. Since smaller cables are used in lower density zones, Distribution Cable Sizing Factors in HM 5.0a are lower in the lowest density zones to account for this effect.

In general, the level of spare capacity provided by default values in HM 5.0a is sufficient to meet current demand plus some amount of growth. Because the model calculates the unit loop investment cost as the total loop investment (including spare capacity), divided by the current loop demand, the resulting unit costs are a conservatively high estimate of the economic cost of meeting current loop demand. This occurs because, in reality, some of the spare distribution plant can and will be used to satisfy additional loop demand in the future, without causing any additional investment cost, thus a larger number of customers will pay for the cable over time. In this sense, the HM 5.0a default values for the distribution cable sizing factors are conservatively low from an economic costing standpoint.

2.6.2. Distribution Pole Spacing

Definition: Spacing between poles supporting aerial distribution cable. . HM 5.0a assumes Aerial Cable in the two densest zones is Block and Building Cable, not support on poles.

Default Values:

Distribution Pole Spacing	
Density Zone	**Spacing**
0-5	250
5-100	250
100-200	200
200-650	200
650-850	175
850-2,550	175
2,550-5,000	150
5,000-10,000	N/A
10,000+	N/A

Note: HM 5.0a assumes Aerial Cable in the two most dense zones are Block and Building Cable, not support on poles.

Support: Distances between poles are longer in more rural areas for a several reasons. Poles are usually placed on property boundaries, and at each side of road intersections (unless cable is run below the road surface in conduit). Property boundaries tend to be farther apart in less dense areas, and road intersections are also farther apart.

Depending on the weight of the cable, and the generally accepted guideline that sag should not exceed 10 feet at mid-span, while still maintaining appropriate clearances as designated by the National Electric Safety Code, very long spans between poles may be achieved. This length may be as great as 1,500 feet using heavy gauge strand and very light cable, or may be shorter for heavier cables.[9] In practice, much shorter span distances are employed, usually 400 feet or less.

"...where conditions permit, open wire spans can approach 400 feet in length with practical assurance that the lines will withstand any combination of weather condition. Longer spans mean savings in construction costs and a net reduction in over-all plant investment, including fewer poles to buy, smaller quantity of pole hardware required, and less construction time. The use of long spans also means a reduction in maintenance expense."[10]

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[9] Bellcore, *Clearance for Aerial Cable and Guys in Light, Medium and Heavy Loading Areas, (BR 627-070-015), Issue 1*, 1987.
see also, Bellcore, *Clearances for Aerial Plant, (BR 918-117-090), Issue 5*, 1987.
see also, Bellcore, *Long Span Construction (BR 627-370-XXX)*, date unk.

[10] Lee, Frank E., *Outside Plant, abc of the Telephone Series, Volume 4*, abc TeleTraining, Inc., Geneva, IL, 1987, p. 41.

2.7. GEOLOGY AND POPULATION CLUSTERS

2.7.1. Distribution Distance Multiplier, Difficult Terrain

Definition: The amount of extra distance required to route distribution and feeder cable around difficult soil conditions, expressed as a multiplier of the distance calculated for normal situations.

Default Value:

Distribution Distance Multiplier, Difficult Terrain
1.0

Support: HM 5.0a treats difficult buried cable placement in rock conditions using five parameters: 1) Distribution Distance Multiplier, Difficult Terrain; 2) Surface Texture Multiplier; 3) Rock Depth Threshold, inches; 4) Hard Rock Placement Multiplier; and 5) Soft Rock Placement Multiplier. The last three of these pertain to the effect of bedrock close to the surface – see Section 2.7.2 through 2.7.5. The first pertains to difficult soil conditions such as the presence of boulders.

While the typical response to difficult soil conditions is often to simply route cable around those conditions, which could be reflected in this parameter, HM 5.0a instead treats the effect of difficult soil conditions as a multiplier of placement cost - see Parameter 6.5, Surface Texture Multiplier. Therefore, the distribution distance multiplier is set to 1.0.

2.7.2. Rock Depth Threshold, Inches

Definition: The depth of bedrock, above which (that is, closer to the surface) additional costs are incurred for placing distribution or feeder cable. The depth of bedrock is provided by USGS data for each CBG, and assigned by the Model to the CBs belonging to that CBG.

Default Value:

Rock Depth Threshold, inches
24 inches

Support: Cable is normally placed at a minimum depth of 24 inches. Where USGS data indicates the presence of rock closer to the surface, HM 5.0a imposes additional costs.

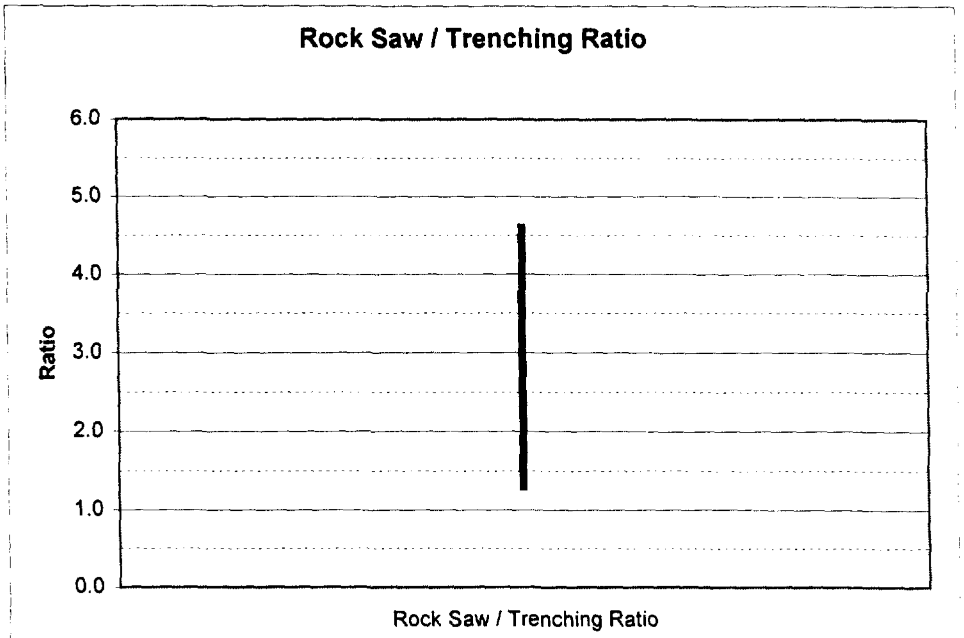
2.7.3. Hard Rock Placement Multiplier

Definition: The increased cost required to place distribution or feeder cable in bedrock classified as hard, when it is within the rock depth threshold of the surface, expressed as a multiplier of normal installation cost per foot.

Default Value:

Hard Rock Placement Multiplier
3.5

Support: A rock saw is used whenever hard rock must be excavated. Information received from independent contractors who perform this type of work is reflected below. Hard rock costs are reflected at the top of the scale.



2.7.4. Soft Rock Placement Multiplier

Definition: The increased cost required to place distribution or feeder cable in bedrock classified as soft, when it is within the rock depth threshold of the surface, expressed as a multiplier of normal installation cost per foot.

Default Value:

Soft Rock Placement Multiplier
2.0

Support: A rock saw or tractor-mounted ripper is used whenever soft rock must be excavated. Information received from independent contractors who perform this type of work is reflected in the figure in section 2.7.3. Soft rock costs are reflected at the lower end of the scale.

2.7.5. Sidewalk / Street Fraction

Definition: The fraction of small, urban clusters that are streets and sidewalks, used in the comparison of cluster area with number of lines to identify cases where high rise buildings are present. To qualify as a small urban cluster, the total land area must be less than .03 square miles and the line density must exceed 30,000 lines per square mile.

Default Value:

Sidewalk / Street Fraction
.20

Support: The sidewalk/street fraction is computed using a .03 square mile (836,352 square feet) cluster, the largest cluster to which it applies. This densely urban cluster is assumed to be square, which means each side of the cluster is approximately 915 feet long. As a result, the roads and sidewalks running around the outside of such a cluster would cover a total land area of approximately 165,000 square feet (915 feet per side times 4 sides times (15 foot wide sidewalk + .5 times 60 foot wide street), or 20 percent of the cluster's total area. The remaining 80 percent, or non-sidewalk/street land area, is occupied by buildings.

2.7.6. Maximum Analog Copper Total Distance

Definition: The maximum total copper cable length that is allowed to carry voiceband analog signals. When the potential copper cable length exceeds this threshold, it triggers long loop treatment and/or the deeper penetration of fiber based DLC.

Default Value:

Maximum Analog Copper Total Distance
18,000 ft.

Support: From the Bellcore document, *BOC Notes on the LEC Networks – 1994, p.12-4,* the following principles are invoked. "To help achieve acceptable transmission in the distribution network, design rules are used to control loop transmission performance. Loops are designed to guarantee that loop transmission loss is statistically distributed and that no single loop in the distribution network exceeds the signaling range of the central office. Based on the most common current design plans applied on a forward-looking basis it is recommended, using Revised Resistance Design (RRD) guidelines, that loops 18 kft in length should be nonloaded and have loop resistances of 1300 Ohms or less. Loops exceeding 18 kft in length should be implemented using Digital Loop Carrier (DLC)." The default value was chosen to be consistent with the minimum distance at which long loop treatment is usually required. [11]

2.7.7. Feeder Steering Enable

Definition: An option that, if enabled, instructs the model to adjust each main feeder route direction toward the preponderance of clusters in a quadrant. In the default state, feeder route directions from the wire center are North, East, South, and West.

[11] Bellcore, *BOC Notes on the LEC Networks - 1994*, p. 12-4.

Default Value:

Feeder Steering Enable
Disabled

Support: The HAI Model will normally assume that four feeder routes emanate from each wire center in the four cardinal directions of north, east, south, and west. When the "Feeder Steering Enable" indicator is selected, the model will adjust the direction of a main feeder route to be closer to the most distant serving area interfaces.

2.7.8. Main Feeder Route/Air Multiplier

Definition: Route-to-air multiplier applied to main feeder distance when feeder steering is enabled to account for routing main feeder cable around obstacles.

Default Value:

Main Feeder Route / Air Multiplier
1.27

Support: Although the feeder route between a wire center and the serving area interface can run in a straight line, such routes may encounter natural obstacles, property boundaries, and the like which cause some degree of rerouting. The Model in default mode assumes right angle routing to accommodate these various obstacles. However, when feeder steering is enabled, the model accounts for non-direct routing through the use of a route-to-air distance multiplier. Because SAIs can be located at any point on the compass, the weighted average right angle routing distance of ($\pi/4$) is the most appropriate solution for the average route to air factor.

2.7.9. Require Serving Areas to be Square

Definition: An option that, if enabled, instructs the model to treat all main clusters as square. In the default state, main clusters are computed as rectangular, with the height to width ratio determined by the process that produces the cluster input data.

Default Value:

Require serving areas to be square
Default setting is disabled

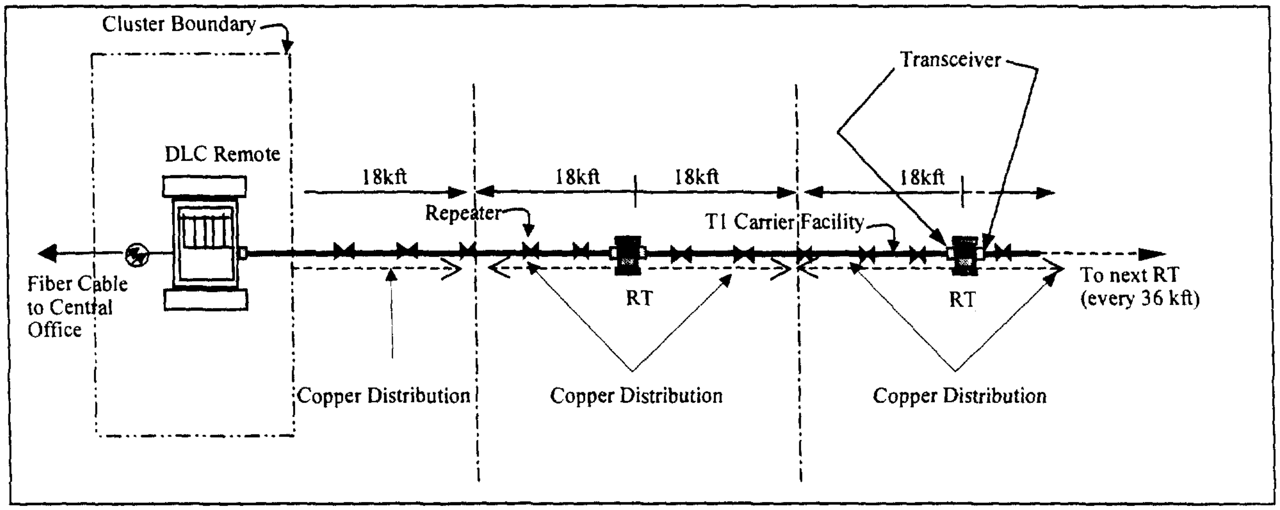
Support: Main clusters are normally treated as if they are rectangular, with the height to width ratio (aspect ratio) determined by the process that produces the cluster input data. The aspect ratio for each cluster is computed by PNR and included in the input data. Normally, a rectangular cluster may be oriented North - South or East - West. However, for consistency with BCPM, the Model allows the user to override the calculated aspect ratio and specify the use of square areas, even though useful information is ignored in doing so.

2.8. LONG LOOP INVESTMENTS

General:

HM 5.0a extends fiber fed Integrated Digital Loop Carrier (IDLC) sufficiently deep into the main cluster to ensure no main cluster loop length exceeds the maximum analog copper loop length. An additional test is performed to determine if the copper distribution cable from the main cluster to other clusters is longer than 18,000 feet. If it is, or if an outlier cluster is connected to the main cluster through one or more remote clusters, HM 5.0a calls for use of T1 on an appropriate number of copper pairs, equipped with T1 repeaters as necessary, feeding small DLC remote terminals (RTs) which are strategically placed along the route to limit the distribution cable to 18 kilofeet. The T1 carrier extensions are assumed to be extended from a Low Density DLC located within the main cluster.

The system configuration for such T1 "long loop" extensions have a number of components described in parameters 2.8.1. through 2.8.8. The relationship among these components is shown in the following figure.



2.8.1. T1 Repeater Investments, Installed

Definition: The investment per T1 repeater, including electronics, housing, and installation, used for T1 carrier long loop extensions.

Default Value:

Repeater Investment, Installed
$527

Support: The cost of a line powered T1 repeater was estimated by a team of experienced outside plant experts with extensive experience in purchasing such units, and arranging for their installation. The equipment portion of this investment is based on supplier information less discount. The repeater spacing is calculated within the model considering the transmission loss of aerial and buried cable, and a transmission objective of 32 dB loss at 772 kHz.

2.8.2. CO Mux Capacity

Definition: The installed central office multiplexer investment required per road cable used for T1 long loop extensions.

Default Value:

Installed CO Mux Capacity
$420

Support: This is the pro rata share of investment for hardware and commons involving multiplexer capacity in the central office utilized by each T1 carrier long loop extension. It was estimated by a team of experienced outside plant experts who were in contact with vendors of appropriate small size IDLC equipment with the capability of being fed by T1 carrier on copper pairs. The material portion of this investment is based on vendor list prices less discount.

2.8.3. Installed RT Cabinet and Commons

Definition: The installed investment per T1 RT used for T1 carrier long loop extensions.

Default Value:

Installed RT Cabinet and Commons
$8,200

Support: The cost of an initial increment of this type small size DLC remote terminal was estimated by a team of experienced outside plant experts who were in contact with vendors of appropriate small size DLC equipment fed by T1 carrier on copper pairs. The equipment portion of this investment is based on vendor list prices less discount.

2.8.4. T1 Channel Unit Investment per Subscriber

Definition: The investment per line in POTS channel units installed in T1 RT used for T1 carrier long loop extensions.

Default Value:

Channel Unit Investment per Subscriber
$125

Support: The cost of appropriate line cards, including a pro rata share of DS1 plug-ins at the CO multiplexer used for this type of Integrated Digital Loop Electronics, was estimated by a team of experienced outside plant experts who were in contact with vendors of appropriate small size DLC equipment suitable for extending bandwidth on conditioned copper pairs. The equipment portion of this investment is based on vendor list prices less discount.

2.8.5. Transceivers

Definition: The installed investment for the transceiver plug-in per T1 RT used to interface with the T1 carrier and to power the repeaters.

Default Value:

Transceiver, Installed
$1170

Support: The cost was estimated by a team of experienced outside plant experts who were in contact with equipment vendors. This cost includes the investment for the transceiver plug-in installed at each end of the T1 carrier feeding the small size RT. The material portion of this investment is based on vendor list prices less discount.

2.8.6. T1 Remote Terminal Fill Factor

Definition: The line unit fill factor in a T1 RT; that is, the ratio of lines served by a T1 remote terminal to the number of line units equipped in the RT.

Default Value:

T1 Remote Terminal Fill Factor
0.90

Support: Fill factors are largely a function of the time frame needed to provide incremental additions. Since line cards are a highly portable asset, facility relief can be provided by dispatching a technician with line cards, rather than engaging in a several month long copper cable feeder addition. Therefore high fill rates should be the norm for an efficient provider using forward looking technology.

2.8.7. Maximum T1s per Cable

Definition: Maximum number of T1s that can share a cable without binder group separation or internal shielding.

Default Value:

Maximum T1s per Cable
8

Support: The use of T-Carrier technology involves the use of high frequency pulse code modulation techniques. High frequency signals can cause interference with other high frequency signals, if a number of electrical engineering characteristics are ignored. While screened cable can be used to isolate copper pairs in cables with very large numbers of T-1's, that is not necessary for small numbers of T-1s in a cable. Experts in outside plant engineering have used the conservative approach of limiting the number of T-1s in a single copper cable sheath to preclude such interference. The default value of no more than 8 T-1s is frequently used in actual design of facilities. Although there are very few cases where the HAI Model now generates long loops on T-1 technology, this limit has been included to ensure that interference does not occur.